Double notches: a zoom into the microphysics of coherent radio emission from pulsars

Great progress in understanding of the ‘W’

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Double notches (dwuwcięcia, wuwcięcia)
Rankin & Rathnasree 1997; Navarro et al. 1997; McLaughlin & Rankin 2004

Detectable only in a handful of pulsars
The notches approach each other at increasing frequency
Always keep the ‘W’ SHAPE with \( W = \Delta \) and depth of \(~40\%\)
Only observed in highly polarised emission (\( \Pi \sim 100\%, 70\% \))

SELECTED PROPERTIES

Dyks, Rudak & Rankin 2007
Microscopic physics is essential for double notches: they are an imprint of elementary microbeam characteristic of a specific radiation process.

Initial (wrong!) idea: Acceleration parallel to velocity?

\[ \theta_R \approx 0.447 \frac{1}{\gamma} \]

e.g. Rybicki & Lightman 1975
General principle of the model (initial version):
Powerful idea:

Explains **doubleness and symmetry**

The elementary microbeam becomes narrower at larger $\nu_{obs}$ for most emission mechanisms

The microbeam is likely observable *in emission* (as a bifurcated emission component, or BFC)
Navarro et al. 1997
J1012+5307 (P = 5.2 ms)

GBT (P. Demorest)

$\Delta t \sim 15$ hours ($>10^6$ single pulses)
Hollow-cone beam does NOT work!
Spatial extent of the emitter makes the notches too shallow

Perry & Lyne 1985
The beam that is needed:

Dyks, Rudak & Rankin (2007)
Curvature radiation in orthogonal polarisation state:

NOT axially symmetric!
Split-fan shape of E-mode CR beam
Reasonable eclipsers (opaque plasma streams) easily produce deep double notches

Dyks, Rudak & Demorest 2009
Traditional sum of gaussians does not work well...
The CR beam
(a single, physical curve has one order of magnitude better $\chi^2$)
Collective plasma effects must amplify the non-coherent beam isotropically (kills several coherency models)

Width of BFC proportional to $\nu_{\text{obs}}^{-1/3}$ (consistent with CR)

High polarisation degree consistent with unimodal emission
Conclusions

Notches and BFCs are intrinsic to the emission mechanism

Angular radiation patterns of classical electrodynamics are directly observed in the sky

Many properties understood: doubleness, symmetry, convergence rate, detailed shape of BFC, general eclipsing geometry, large depth of notches (compact absorber not needed anymore).
The curvature radiation is the only natural emission mechanism consistent with the split-fan topology of the microbeam, and with the BFC’s shape and convergence rate.

Successful physical fits to a radio pulse component have been performed first time in history

=> important impact on the coherency models